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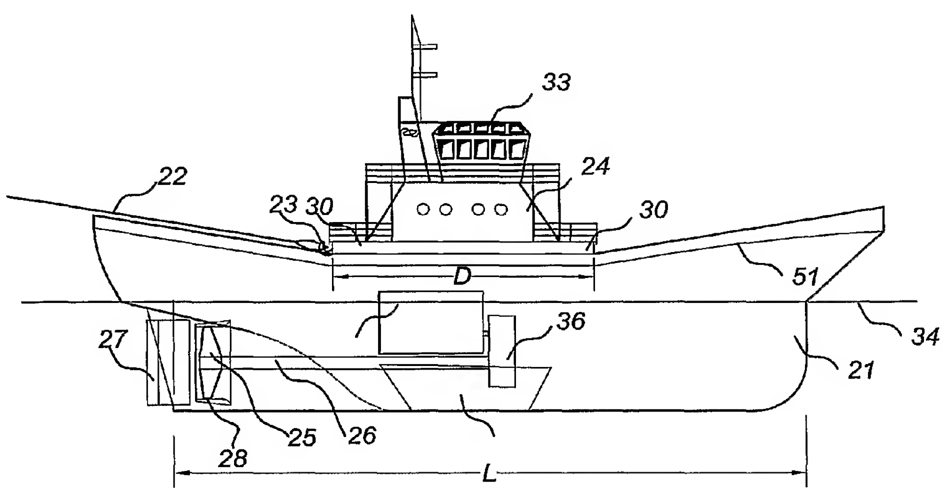
(54) **Title:** TUGBOAT WITH TOWING GEAR THAT CAN TURN THROUGH 360 DEGREES



(57) **Abstract:** The invention relates to the design for a tug provided with towing gear that can turn through 360 degrees in the horizontal plane, where the ratio of both the hull length L of the tug and the lateral distance W between the two propulsion units have values with respect to the diameter D of the carousel towing gear such that it is possible to manoeuvre the tug very accurately and to make it turn quickly and in a controlled manner at relatively high towing speeds, with adequate stability.

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TUGBOAT WITH TOWING GEAR THAT CAN TURN THROUGH 360 DEGREES

The invention relates to a tug having an elongated hull of length (L) and two propulsion units located perpendicularly with respect to the longitudinal axis some distance apart, wherein there is towing gear that can turn through 360° in the horizontal plane on the hull, the point of engagement of said towing gear describing a circle with a diameter D.

Ships in ports and sailing regions where there are limitations are usually assisted by one or more tugs with powerful propulsion units. In order to achieve a high pulling force, the tugs are provided as standard with one or more large diameter propellers and with so-called propeller nozzles around the propeller.

Modern tug designs are characterised by two or more rotary propulsion units under the hull, the propulsion units being installed at either the stern or the bow of the tug and the towing gear being installed at the opposite end. When towing, the hull of the tug is turned mainly in the direction of the towing line and manoeuvred into the desired position by means of the rotary propulsion units. It is true that these rotary propulsion units provide good manoeuvring characteristics, but this goes hand in hand with high purchasing and maintenance costs, a lower propulsion output and, as a result of the complexity, reduced reliability.

A new development relates to tug designs provided with towing gear that can turn through 360 degrees in the horizontal plane. These are designs where a fixed ring is fixed on the deck and a turning ring is able to rotate around it. The towing line is attached to this ring by means of a tow hook, towing winch or the like. Characteristic features of this towing gear are, on the one hand, the complete 360 degrees all round freedom of towing and, on the other hand, the shift in the point of application of the towing force from the middle of the tug to the side of the hull. As a result the towing force torque multiplied by lever arm (the so-called heeling moment) decreases, as a result of which the tug will be less prone to capsizing. One example of this is disclosed in WO 0130650.

However, it is found in practice that for tugs with towing gear that can turn through 360 degrees conventional hull shapes and propulsion units do not provide the desired manoeuvrability and stability that is needed in order to be able to manoeuvre quickly and accurately in a restricted channel and that make it possible to make the hull turn in a controlled manner from forwards, to sideways, to backwards and vice versa at high towing

speeds.

A first proposal to solve this problem is a disc-shaped tug as described in DE 881 312 C. It relates to a disc-shaped tug provided with a circular section with a small carriage therein that turns in the section by means of rollers. The towing line is connected to this small carriage by means of a tow hook. This design has a carousel towing gear with two propulsion units. This tug does not have a pronounced longitudinal axis but is disc-shaped with an equal length and breadth. As a result the design can sail only at low speed and because of the high resistance has a high fuel consumption. In addition, the large width of the hull also gives rise to severe limitations in narrow channels.

The aim of the present invention is to provide an installation that eliminates the abovementioned disadvantages. That is to say a tug design with towing gear that can turn through 360 degrees, by means of which rapid and accurate manoeuvring and high dynamic forces in combination with adequate stability are achieved and where the hull can be turned round in a controlled manner even at relatively high towing speeds.

This aim is realised in a tug as described above, where in

$W / D > 0.5$

$L / D > 1.5$ and $L / D < 3.2$

The following characterising parameters are defined for the design:

Hull length (L): standard definition of length between perpendiculars for ships (Load Lines as used in maritime legislation in metres. This is the length between, at the bow, the perpendicular through the intersection with the waterline and, at the stern, the perpendicular through the rudder post or steering gear. Here the parameter L is characteristic for the hydrodynamic interplay of forces when the hull is towed laterally through the water (larger L means larger surface area and higher force) and characteristic for the manoeuvrability of the hull (larger L means poorer manoeuvrability).

Lateral distance between the propellers (W): the lateral horizontal distance between the two propellers, measured perpendicularly to the longitudinal axis in metres. Here the parameter (W) is characteristic for the of the steering torque between the two propellers and the available manoeuvrability of the hull.

Diameter of the carousel towing gear (D) = 2 x R: here R is the horizontal distance between the axis of rotation of the towing gear and the point of application of the towing line force in metres. Here the parameter (D) is characteristic of the stability behaviour of the tug (larger D means smaller heeling moment and greater stability).

Research has shown that if ratios between L and D are chosen well advantageous hydrodynamic forces are obtained as well as good manoeuvrability of the hull. Likewise, with good ratios between W and D good manoeuvring characteristics are obtained as well as good stability against pulling over. As a result it is possible to turn the hull round in a controlled manner even at relatively high towing speeds. In practice this will correspond to assistance speeds of about 6 - 8 knots.

By this means it is possible to manoeuvre the tug very accurately and quickly and to make it turn in a controlled manner at relatively high towing speeds, with adequate stability.

In particular it is found that very good results are obtained with the following ratios between the parameters D, L and W.

$$L / D > 2 \text{ and } L / D < 2.8$$

$$W / D > 0.6$$

The above is based on conventional propulsion capacities.

By installing higher propulsion capacities it becomes possible with these larger ratios to manoeuvre in a controlled manner at even higher speeds.

According to a further advantageous embodiment the propulsion units comprise propellers driven by means of conventional fixed propeller shafts. With this arrangement the motors of the propulsion units are installed at approximately halfway along the length and drive the propellers beneath the stern by means of the propeller shafts. The propeller shafts extend parallel to the longitudinal axis of the tug, possibly with a slight downward angle of inclination (less than 10 degrees). This arrangement combines low investment and maintenance costs with a high propulsion output and, as a result of the simplicity of the installation, high reliability.

According to a further advantageous embodiment the propellers are provided with large rudders to increase the steering forces (steering moment) further. A particular embodiment of this relates to a so-called flap rudder; here the rear part of the rudder is provided over the entire height with a flap that can be turned separately. When the rudder is turned this flap assumes a larger rudder angle. As a result of this configuration larger lift coefficients are achieved, as a result of which the tug steers/turns more rapidly.

According to a further advantageous embodiment the propellers are installed in rotatable propeller nozzles, possibly provided with an additionally installed flap rudder. Rotatable propeller nozzles are provided with a vertical shaft and turn about the centre of

the propeller. These are very effective for directing the full flow of the propeller (since the propeller nozzle encloses the entire propeller) and also offer the possibility of being able to direct the flow when under reverse thrust as well; this is in contrast to a rudder (positioned behind the propeller) that has an effect only in the case of forward thrust.

According to a further advantageous embodiment the tug is provided with higher thrust by using larger engines and propellers. Current tugs with propeller drives and lengths of the order of 24 - 28 metres have a thrust of the order of 30 - 50 x 10^3 kgf (measured at pulling force at zero speed on a fixed bollard, the so-called bollard pull value), roughly 1 - 1.5 times the length of the tug. By increasing this to values of 60 - 80 tonne or higher, roughly 2 - 3 times the length of the tug, not only does the towing force increase but also, according to the proposed configuration, the possibility of manoeuvring safely and accurately at speeds above 8 knots.

According to a further advantageous embodiment the tug is provided with so-called controllable pitch propellers, where the propeller blades are able to turn relative to the propeller hub (pitch) and are able continuously to control the thrust from forward to reverse. As a result it is possible to manoeuvre even more rapidly, accurately and safely.

According to a further advantageous embodiment the propulsion units are positioned in the fore 25 % of the length or aft 25 % of the length so as in this way to achieve as high as possible a steering moment with respect to the centre of gravity close to 50 % of the length.

According to a further advantageous embodiment the hull shape above water is provided with adequate watertight buoyancy to prevent water welling up onto deck and the hull being pulled below water when turning round at relatively high towing speeds. This can be achieved by making the hull shape above water wider and raising the deck. As a result of the stabilising effect of the carousel towing gear, this raising of the point of application of the towing force does not give rise to any problem, in contrast to ordinary towing gears. Model trials have shown that if the watertight volume above the waterline is more than 60 % of the watertight volume below the waterline, the hull has sufficient buoyancy to prevent it being pulled underwater by the dynamic pulling forces at relatively high towing speeds. Values of 80 % and more also give good results. In order to achieve this aim in an optimum manner this buoyancy must as far as possible be evenly distributed over both the fore part and the stern part to prevent the part with lower buoyancy still being pulled underwater at high sideways speeds. A higher deck in the fore part also offers the

option of installing the crew's quarters below the higher deck above the waterline in accordance with the requirements of maritime legislation. In practice this means that the deck is at least 2.30 m above the waterline at the location of the quarters.

According to a further advantageous embodiment the width of the hull above the waterline increases appreciably in the mid section of the boat. What is achieved by this means is that below the waterline the resistance along the ship decreases and above water the extent of the stability and buoyancy increases. Moreover, the greater width above water also offers protection to the propellers when mooring at quays. These advantages are already achieved with a 10 % greater width at the location of the deck compared with the waterline, measured in cross-section between 40 % and 60 % of the length L. In addition, this shape also has good flow characteristics at high sideways speeds because the shape guides the water underneath the hull.

According to a further advantageous embodiment, a small auxiliary thruster is installed in the fore part so as to be able to manoeuvre accurately at low speeds and in reverse at high speeds.

According to a further advantageous embodiment the length of the tug is chosen to be just less than 24 m in length, since this is an international legislation limit to which specific requirements are related. The choice just below this length yields appreciable advantages in relation to building and operational costs. Advantageous length values will be between 21 and 24 m. Use of the L / D and W / D ratios yields a tug design with the following dimensions: L = 23.95 m, D = 9.30 m and W = 7.00 m. (L / D ratio = 2.58 and W / D ratio = 0.75).

According to a further advantageous embodiment the hull is provided with one or more skegs beneath the hull so as to make the hydrodynamic resistance and forces increase. A good solution is achieved by using these in the mid section, as a result of which the resistance does increase but the manoeuvrability is impeded to a minimum extent.

The invention will be explained in more detail below with reference to the illustrative embodiments shown in the drawings.

Figures 1a and 1b show, diagrammatically, a side view and plan view of a conventional tug.

Figures 2a to 2d shows (sic), diagrammatically, a side, plan, front and rear view, respectively, of the tug according to the invention.

Figure 3 shows, diagrammatically, the interplay of forces of the carousel towing gear

at 0 degree heeling angle in Fig. 3a and at 15 degree heeling angle in Fig. 3b.

Figure 4 shows, diagrammatically, the interplay of forces by the propellers without rudder action.

Figure 5 shows, diagrammatically, the interplay of forces when the rudder action is used.

Figure 6 shows, diagrammatically, the interplay of forces when rotatable propeller nozzles are used.

Figure 7 shows, diagrammatically, a side and frontal view of the hull provided with more buoyancy.

Figure 8 shows, diagrammatically, in cross-section at halfway along the length, the hull with an increasing width above the waterline.

A conventional twin screw tug with the following components is shown in Fig. 1: hull 1, towing line 2, tow hook 3 permanently connected to deckhouse 4, propulsion propeller 5, propeller shaft 6, rudder 7, propeller nozzle 8 and main engine 9. The wheelhouse 13 and the waterline 14 are also shown. In addition, the length L and the lateral distance between the propellers W are shown for this tug.

In Fig. 2 the tug according to the invention is shown, with the hull 21, towing line 22, deckhouse 24, propulsion propellers 25, propeller shafts 26, rudders 27, propeller nozzles 28, main engines 29, wheelhouse 33 and waterline 34. In addition, the towing gear 30 that can turn through 360 degrees is shown with inner ring 31 and outer ring 32, with the tow hook 23 joined thereto. The effective diameter of the towing gear 30, that is to say of the point of application, is indicated by D. There is a gearbox 36 and optional skegs (fins) 35 in the mid section to increase the lateral resistance and dynamic forces. The figure shows the length L and the lateral distance between the propellers W. For the sake of clarity the superstructure 24 and the wheelhouse 33 are not shown in Figs 2c and 2d.

Fig. 3 shows a cross-section of the present invention with the D and W indicated therein. The inner ring 31, the outer ring 32, to which the tow hook 23 is fixed, and the towing line 22, attached to the latter, are shown. For comparison, the towing lines 43, 47 attached on the central axis 45 of a conventional tug are additionally also shown. The lower point of engagement of the towing force as a result of the carousel towing gear and, consequently, the lower heeling moment is clearly visible both at zero heeling angle and at 15 degree heeling angle. The effect shown is intensified at larger heeling angles (30 degrees and more). The point of engagement of the towing force is the point of intersection of

towing line 44 (at 0 degree heeling angle) and 46 (at 15 degree heeling angle), that is to say tow hook 23.

Although in this example the point of engagement with the 360° towing gear is a tow hook 23, it must be understood that other constructions are also possible. For instance, it is possible to use a winch or drum and in that case the point of engagement is the point where the line or chain leaves the towing gear.

In Fig. 4 the tug according to the invention is shown with the thrust 37 generated by the propellers 25. The rudders 27 are both in the mid position. With respect to the centre of rotation 38, both thrusts from the individual propellers exert a lever arm w1 and w2, a torque 42, as a result of which the tug starts to turn. It can clearly be seen here that by increasing distance W, the lever arm w1 and w2, and consequently the available turning moment, increase proportionately.

In Fig. 5 both the conventional tug and the tug according to the invention are again shown in plan view, but now in combination with rudder action. By turning the right-hand rudder 27 the direction of the thrust and the lever arm w1 and w2 with respect to the centre of rotation change in the case of forward thrust. In the case of reverse thrust the left-hand rudder positioned behind the propeller has no steering action.

The effect of a rotatable propeller nozzle 39 in the case of the present invention is shown in Fig. 6. By turning the nozzle a steering action both in the case of forward and in the case of reverse thrust is supplied. The substantial increase in the lever arm w3 with respect to the lever arm w1 in Fig. 5 can again clearly be seen. A similar effect can also be achieved by positioning both one or more rudders behind the propeller as well as in front of the propeller. It can furthermore be seen from the figures that as the propeller is positioned further away from the centre of rotation 38 the lever arm w2 and w3 will increase proportionately. Therefore, a good position for the propeller/rudder/propeller nozzle is between 0 and 25 % of the length measured from the bow or stern.

In Fig. 7 the watertight volume above the waterline 34 is shown. The watertight volume below the waterline 48 and the watertight volume above the waterline 49 are shown. The uniform distribution of the watertight volume above the waterline both in the fore part and in the stern part is also clearly shown.

In Fig. 8 the cross-section at halfway along the length is shown; the waterline 34 and the ship's side 50 that increases in width above the waterline and at deck height has a value b that is at least 10 % wider than at the waterline are shown.

Although the invention has been described above with reference to a preferred embodiment, numerous modifications can be made without going beyond the scope of the present invention. The definition of the hull length has been chosen as a measure for the turnability of the hull because this is a conventional measurement in shipping, but other length definitions can also be used provided that these are related to the resistance and turnability of the hull. In this context consideration can also be given to the widely used maritime length parameter related to 96 % of the load line length at 85 % of the smallest depth. Furthermore, the design is not restricted to conventional propeller drives, but other arbitrary drive systems (such as Voith Schneider drives) can also be used. Moreover, it is not essential that the propellers are positioned at precisely the same position along the length, provided that there is adequate lateral spacing to generate a high steering torque. The distance from the applied towing force with respect to the central axis has been taken for the diameter (D) because this distance is characteristic for the reduction in the heeling moment at larger heeling angles. Other configurations related to this distance also fall within the scope of this invention.

Claims

1. Tug having an elongated hull of length (L) and two propulsion units located perpendicularly with respect to the longitudinal axis some distance apart, wherein there is towing gear that can turn through 360° in the horizontal plane on the hull, the point of engagement of said towing gear describing a circle with a diameter D, characterised in that

   $W / D > 0.5$

   $L / D > 1.5$ and $L / D < 3.2$

2. Tug according to Claim 1, wherein

   $W / D > 0.6$

   $L / D > 2.0$ and $L / D < 2.8$

3. Tug according to one of the preceding claims, wherein the propulsion units comprise propellers provided with flap rudders.

4. Tug according to one of the preceding claims, wherein the propulsion units comprise propeller nozzles that are constructed such that they can turn.

5. Tug according to one of the preceding claims, wherein said propulsion units comprise controllable pitch propellers.

6. Tug according to one of the preceding claims, wherein, in the use situation, the watertight volume of the hull above the waterline is at least 60 % of the watertight volume of the hull below the waterline.

7. Tug according to one of the preceding claims, wherein the width of the hull above the waterline at the location of the deck is at least 10 % wider than the width of the hull below the waterline.

8. Tug according to one of the preceding claims with a length L of between 21 and 24 m.

9. Tug according to one of the preceding claims, wherein the thrust in 1,000 kgf is greater than twice the length L in metres.

10. Tug according to one of the preceding claims, wherein the hull shape at the bow and/or stern has a rounded shape (in the horizontal plane).

11. Tug according to one of the preceding claims, wherein the deck is at such a height above the waterline that the crew's quarters (cabins) are installed above the waterline.

12. Tug according to one of the preceding claims where a small auxiliary thruster is

installed (in the bow).

13. Tug according to one of the preceding claims, wherein the propulsion units are positioned in a region of less than 25 % of the total length of the tug from one end thereof.

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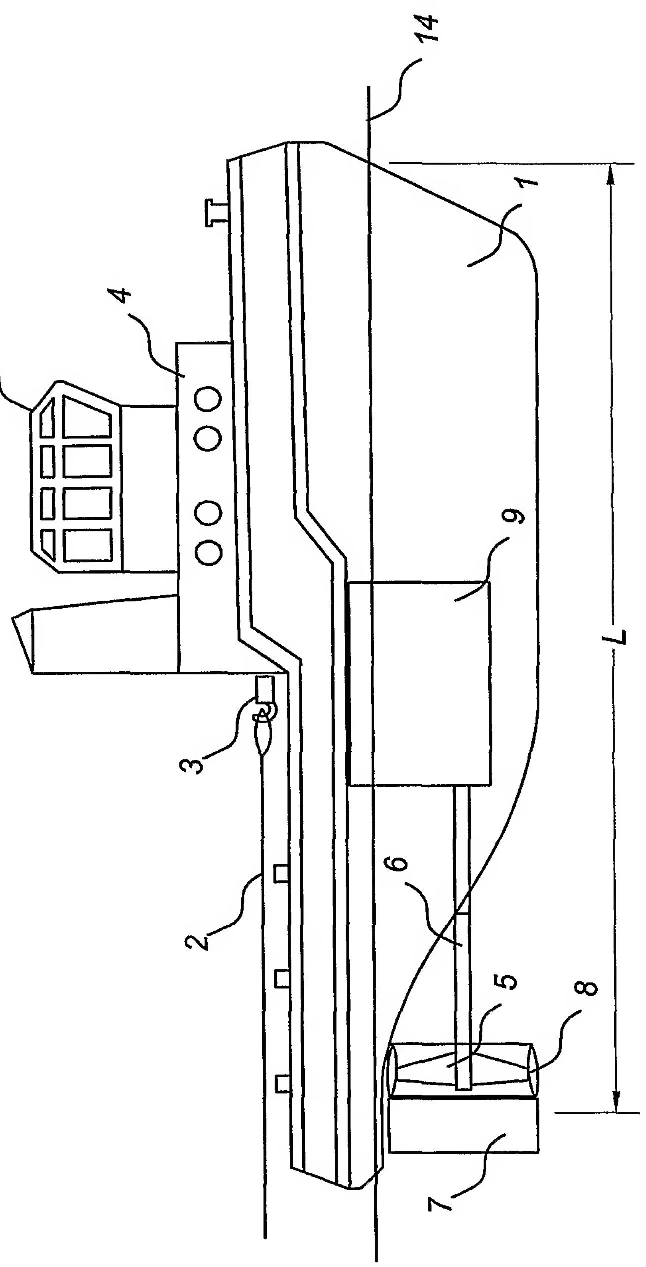

Fig. 1a

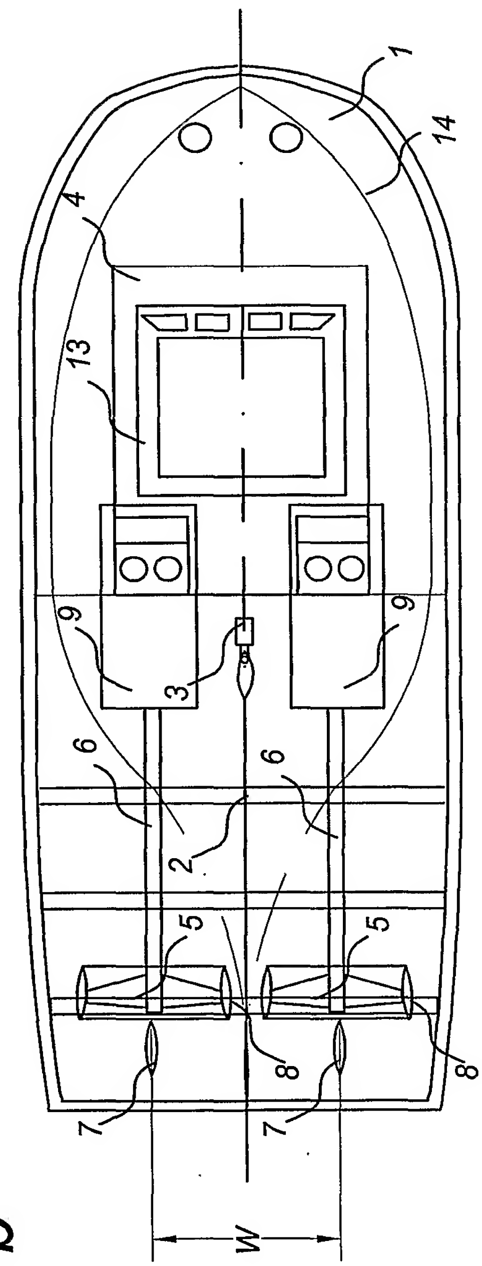

Fig. 1b

Fig. 2a

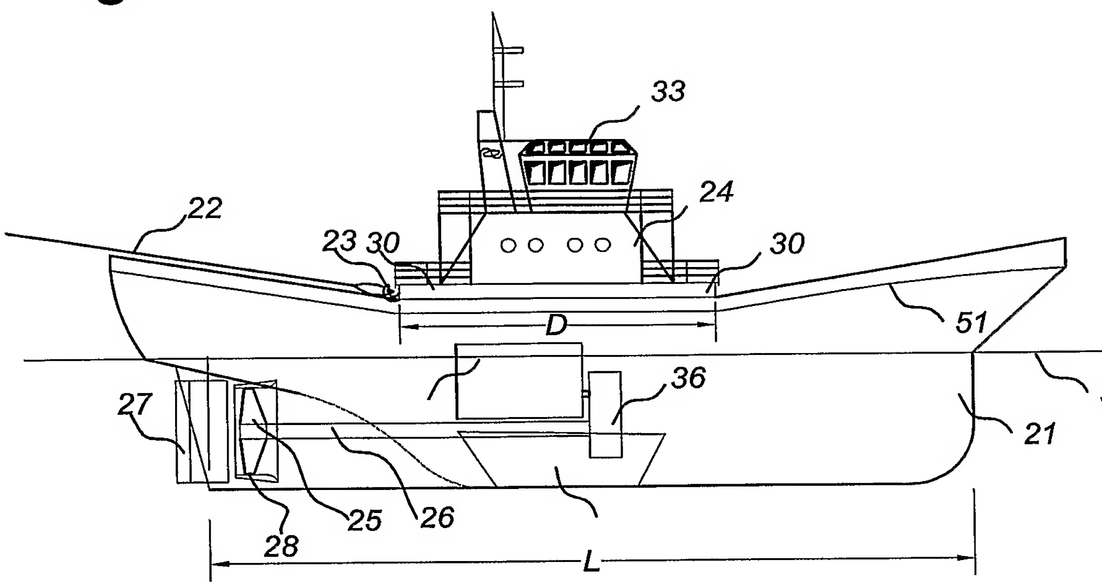
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Fig. 2b

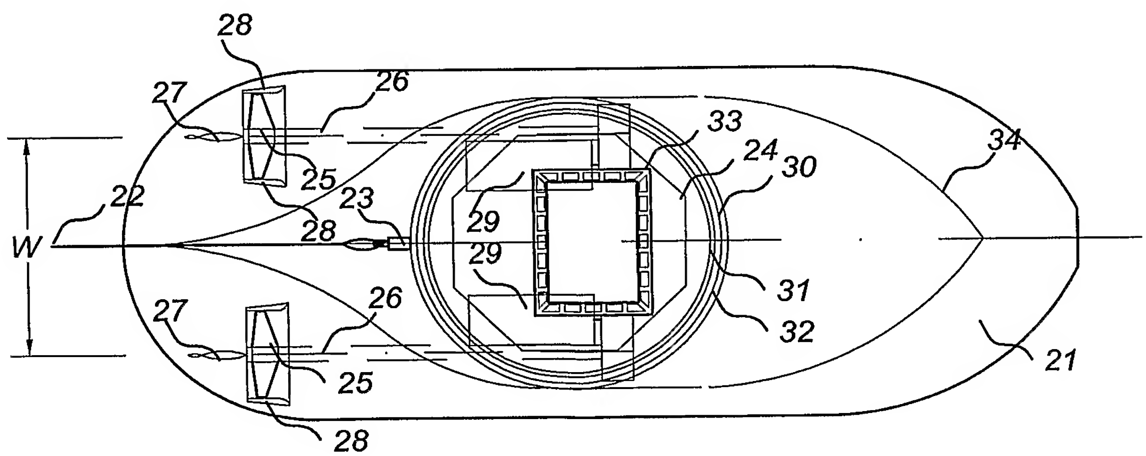
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Fig. 2c

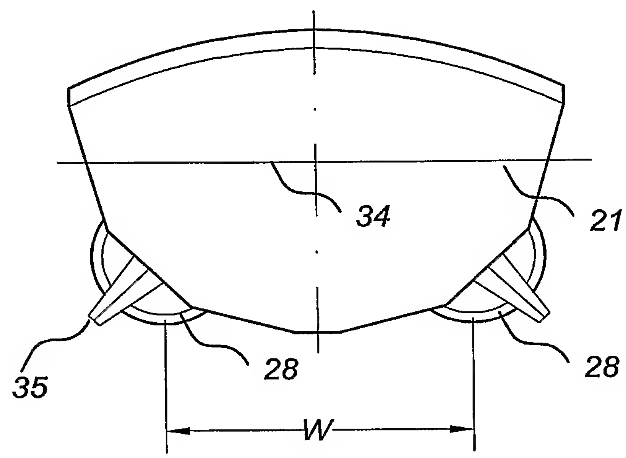


Fig. 2d

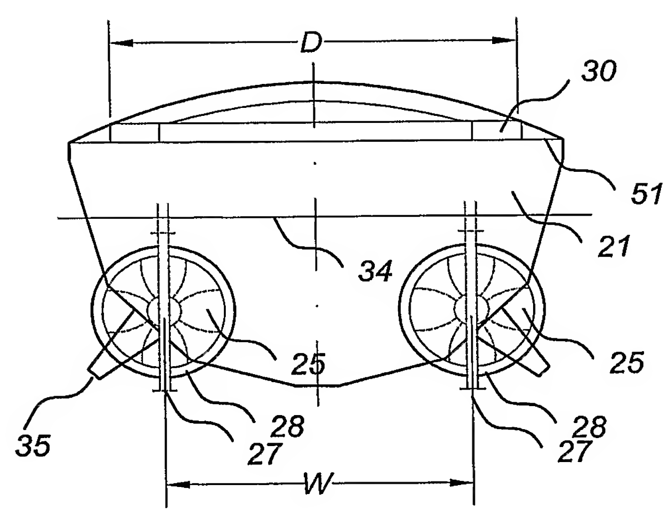


Fig. 3a

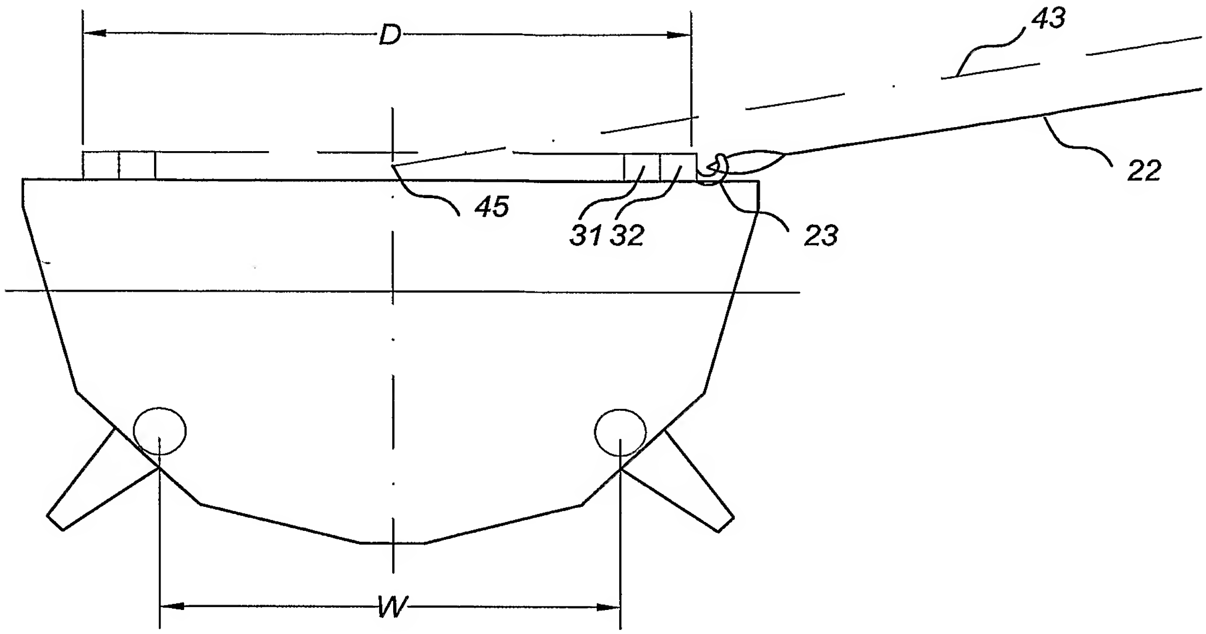
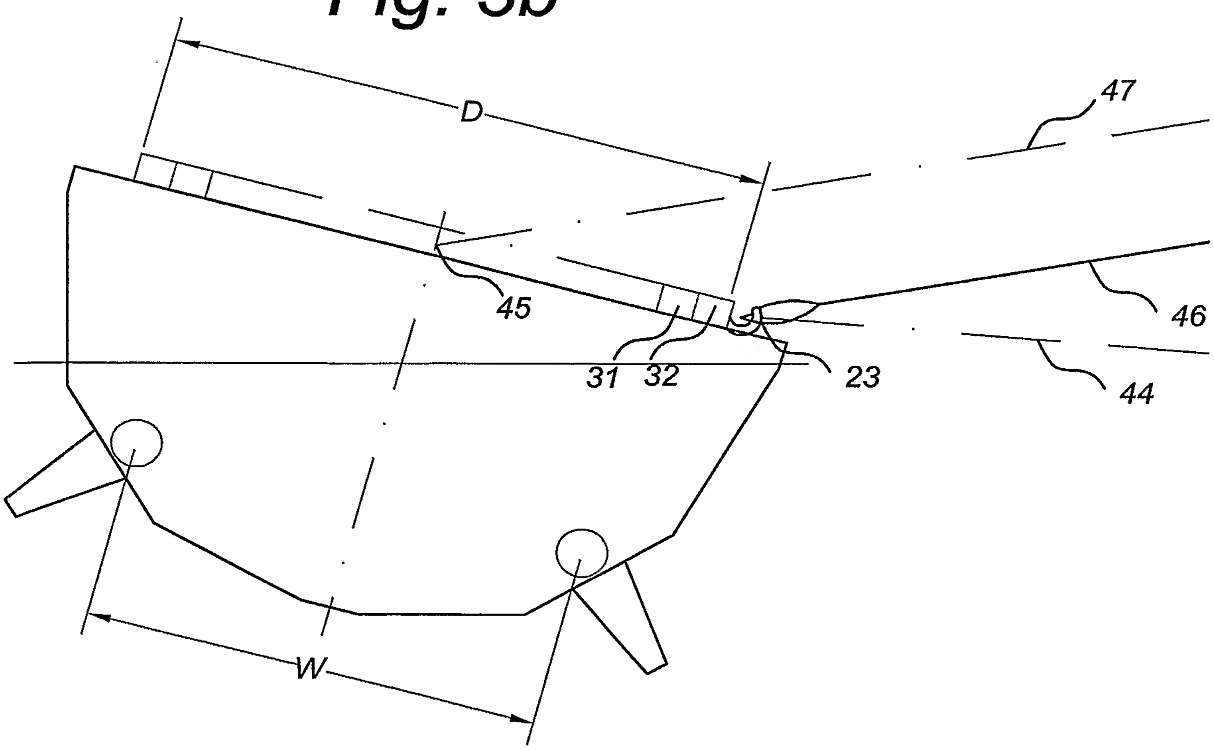


Fig. 3b



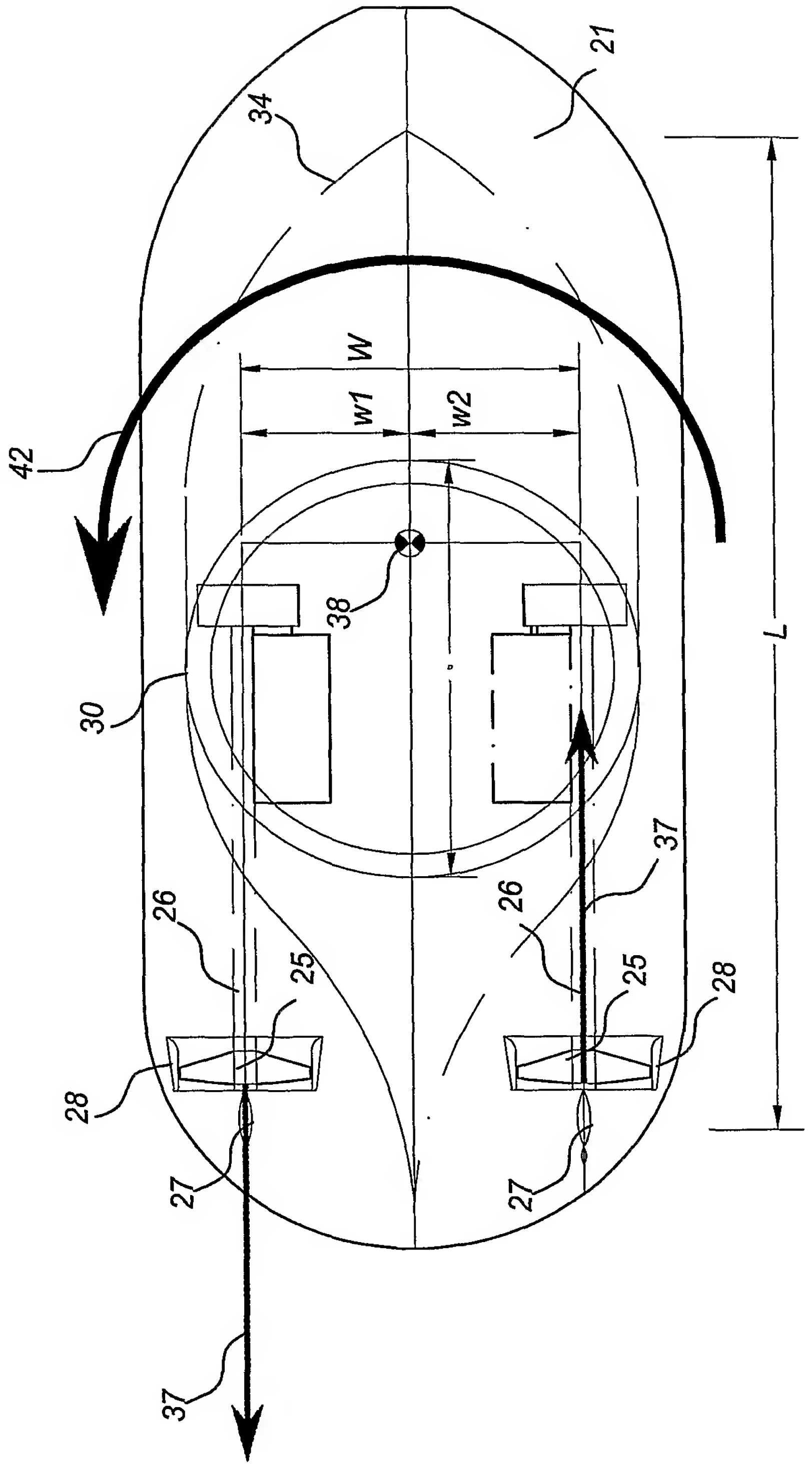


Fig. 4

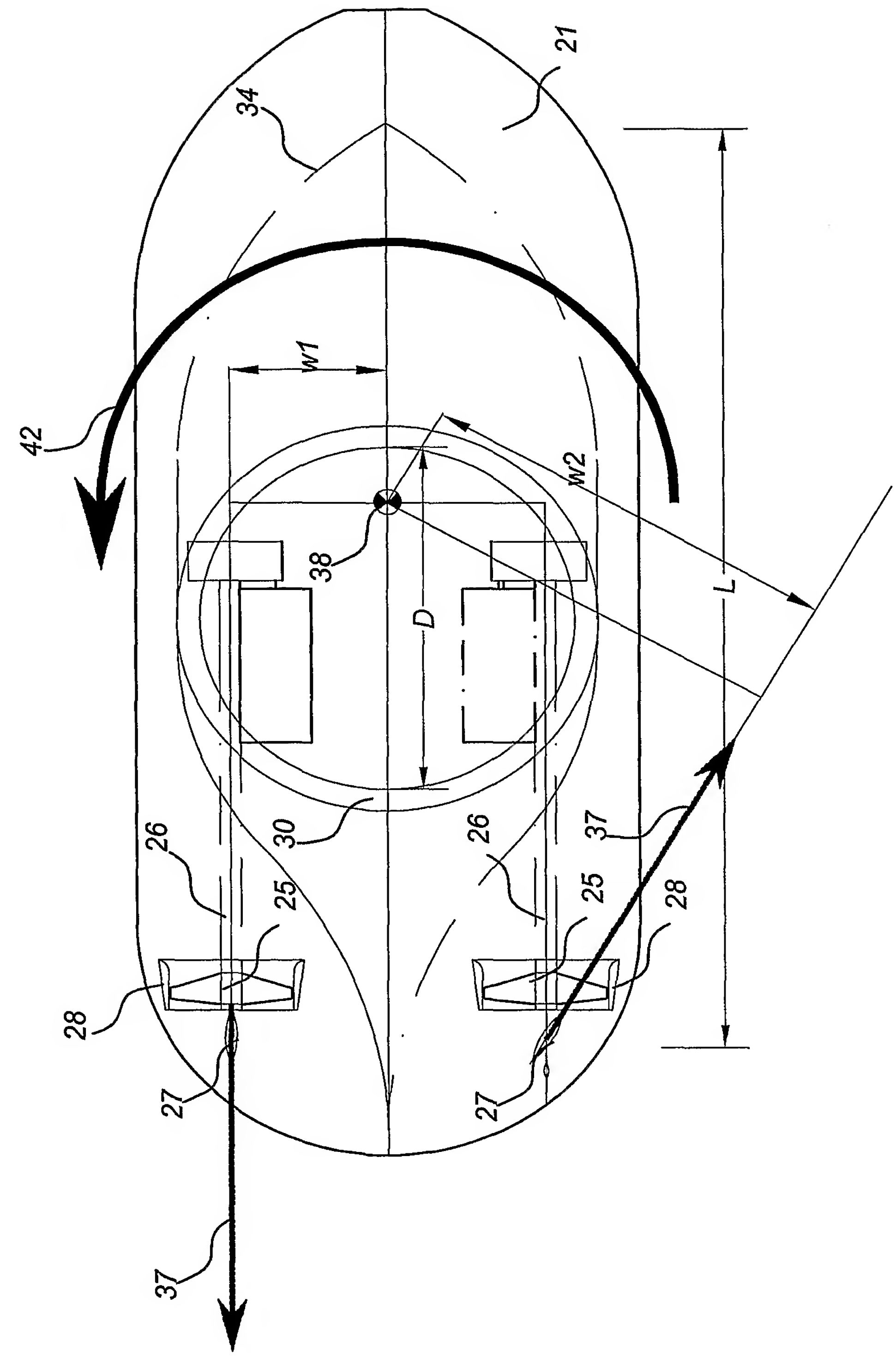


Fig. 5

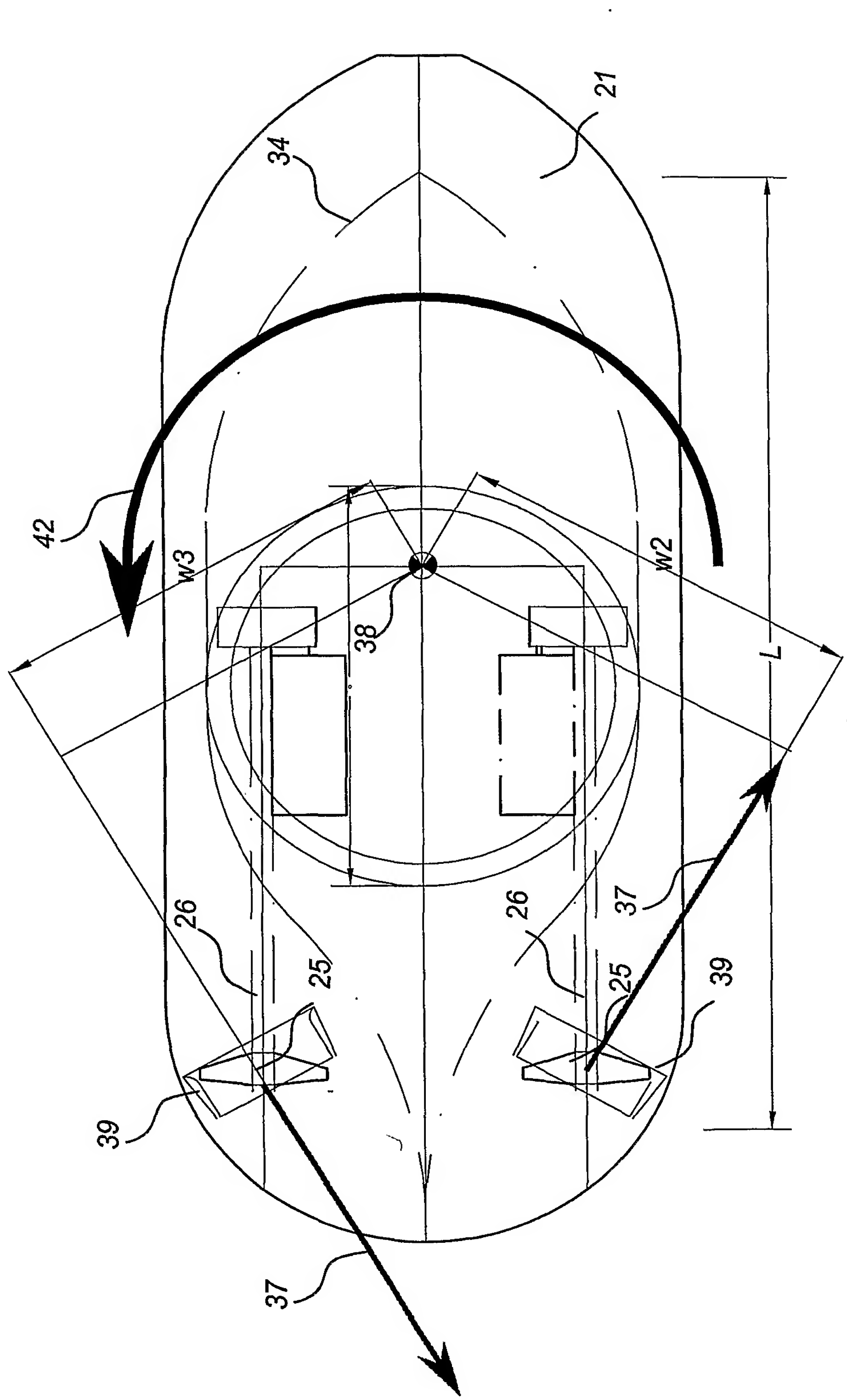


Fig. 6

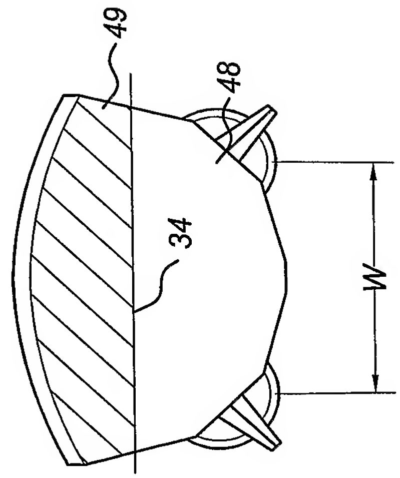


Fig. 7b

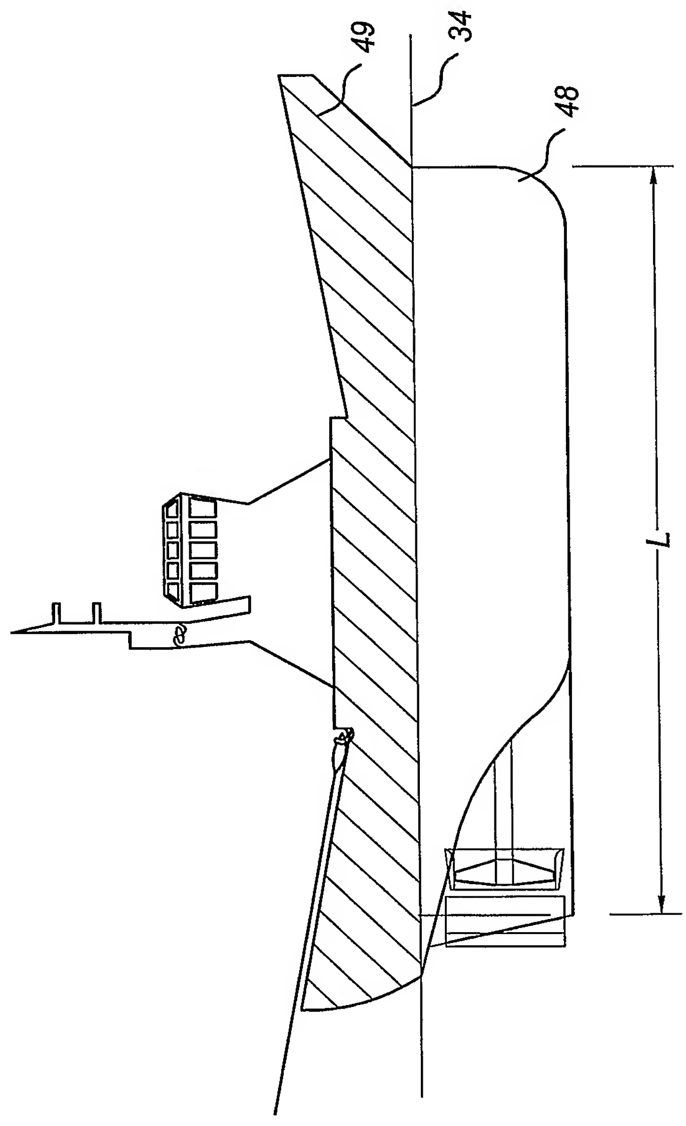
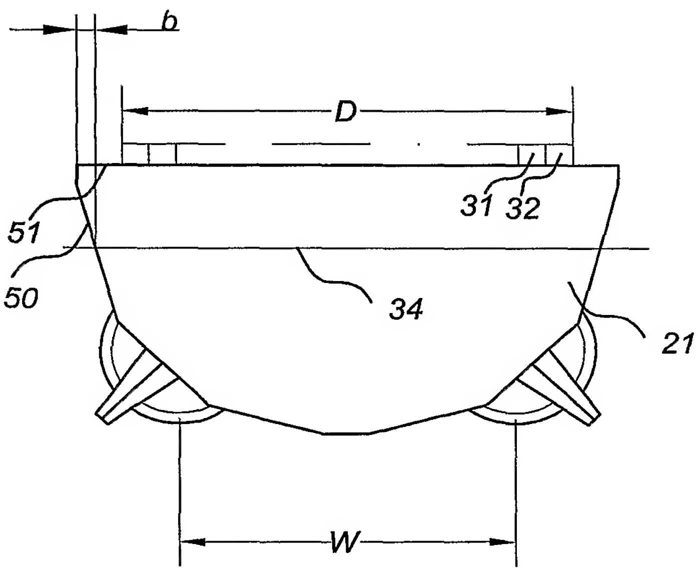


Fig. 7a

Fig. 8



INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL2004/000769

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B63B35/68

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01/30650 A (IMC CORPORATE LICENSING BV; M. VAN DER LAAN) 3 May 2001 (2001-05-03) cited in the application abstract; figures	1
A	EP 0 672 582 A (AQUAMASTER-RAUMA LTD) 20 September 1995 (1995-09-20) abstract; figures	1
A	FR 1 492 939 A (T VAN DER KUIL) 25 August 1967 (1967-08-25) figure 7	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 July 2005	02/08/2005

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT
rmation on patent family members

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TITLE: TUGBOAT WITH TOWING GEAR THAT CAN TURN THROUGH 360 DEGREES

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ABSTRACT:

CHG DATE=20060602 STATUS=O>The invention relates to the design for a tug provided with towing gear that can turn through 360 degrees in the horizontal plane, where the ratio of both the hull length L of the tug and the lateral distance W between the two propulsion units have values with respect to the diameter D of the carousel towing gear such that it is possible to manoeuvre the tug very accurately and to make it turn quickly and in a controlled manner at relatively high towing speeds, with adequate stability.